4. Coupling environmental and social sustainability: countries' trajectories, pathways and policies towards sustainable job creation

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1. INTRODUCTION

Since the Paris Agreement, progress towards reducing global greenhouse gas emissions while ensuring social sustainability of such efforts has been slow to materialize. Yet, the most recent reports by the International Renewable Energy Agency (IRENA) and the International Labour Organization (ILO) (IRENA and ILO 2022) and the International Energy Agency (IEA) (2022a) suggest that there are plenty of emerging opportunities to couple decarbonization with job creation in new green sectors and to leverage these opportunities in order to generate further jobs across the economy. However, investment and long-term financial commitment are needed to seize these green job opportunities and to restructure economies, beginning with their energy systems. The energy sector accounts for at least a third of all emissions globally. Generating electricity in a more efficient way will play a systemic role in decoupling, since all economic sectors rely on electricity generation. Sustainable electricity generation is also essential to the creation of employment in a sustainably expanding economy.

In its most recent road map towards "Net Zero by 2050", the IEA has highlighted the need for a dramatic acceleration in clean energy investment, the rapid deployment and diffusion of available technologies, and the implementation of climate policies across more than 400 sectoral and technology milestones (IEA 2021). The IEA has also denounced the fact that countries' commitments have often fallen short in implementation. The rate of energy efficiency improvement must increase to three times the average rate achieved over the last two decades. A 4 per cent per year average increase till 2030 is necessary if economic growth is to be decoupled from energy consumption. On the technological end, this requires a fivefold increase in energy capacity from solar and wind technologies, as well as the exploitation of wide opportunities arising from advanced batteries, hydrogen electrolysers, and direct air capture and storage. To support this energy transition will demand an estimated US$90 billion of public investment to be mobilized globally and new measures to redirect finance away from new coal plants and to crowd in further clean energy investments to the tune of more than US$4 trillion.

In this chapter, we focus our attention on the different pathways and policies that countries need to pursue in order to decouple job creation from carbon dioxide emissions. We start from an empirical assessment of the extent to which countries have been progressing towards increasing environmental sustainability and job creation. We focus on the period 2014–2018 and combine different sources of data available for over 100 countries, including several low- and middle-income countries. Time points before the Paris Agreement and before the global pandemic are used to define countries' data points in order to study the key relationships linking jobs creation to carbon dioxide emissions, energy efficiency, installed renewable capacity at the country level, and global shares in carbon dioxide emissions. We highlight several stylized facts and identify countries that have been clear outliers in terms of their performance, whether positive or negative.

Behind each of these countries' trajectories are heterogeneous factors driving or constraining decarbonization. In the second part of the chapter, we focus on five main potential decarbonization pathways and related windows of green jobs opportunity:

(a) planned phase-out or exit from fossil fuel industry extraction for energy generation and export (coal and oil);
(b) decarbonization of existing energy-intensive industries (such as iron and steel, chemicals and plastics, and cement);
(c) development of new renewable technology industries (solar, wind and hydrogen);
(d) development of new and retrofitting of existing energy infrastructure (main grid, mini-grids, storage, export facilities);
(e) circular economy models linking (b), (c) and (d) and mainstreaming them across industries.

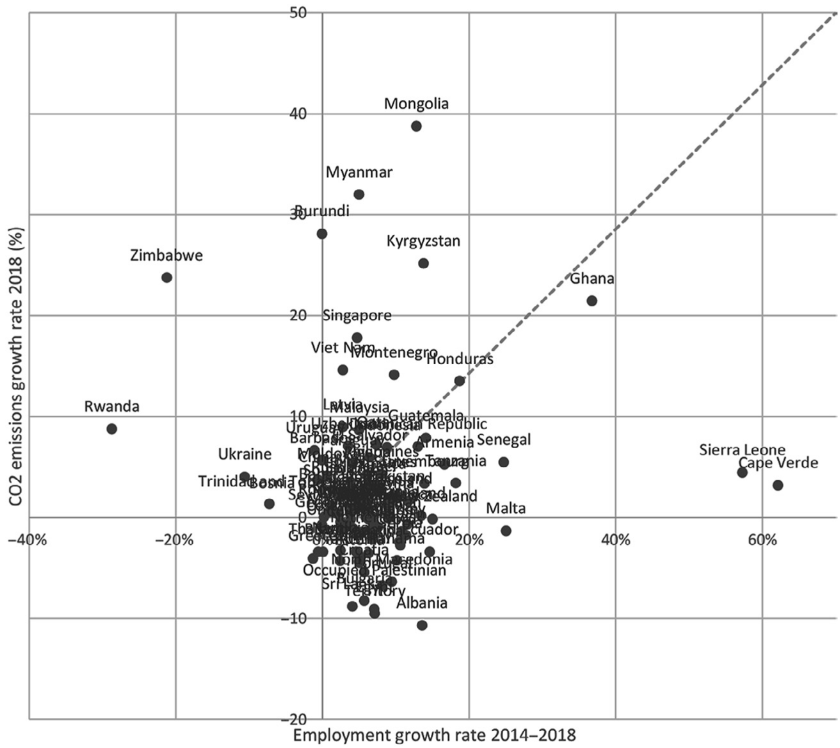
These are essential pathways for sustainable industrialization, but their ramping up will need to be socially inclusive and create jobs, especially in developing countries. Such pathways can only be pursued if countries deploy well-designed industrial policies to coordinate sector-specific decarbonization efforts as well as seize opportunities for job creation. I discuss different types of industrial policy instruments by providing examples from Chile, South Africa, the United Republic of Tanzania, and Thailand. Each country case study highlights both challenges and the potential transformative role of certain initiatives.

2. MAPPING COUNTRIES' SUSTAINABLE STRUCTURAL TRANSFORMATION: STARTING POINTS AND STYLIZED TRAJECTORIES

Empirical evidence shows that during the period 2014–2018 the relationship, globally, between employment generation and the latest rate of growth in carbon dioxide emissions (2018) has largely remained coupled. However, there are signs that some countries have started recording a *slower than proportional* acceleration in carbon dioxide emissions. This means that, despite the efforts made, most countries are finding it difficult to create more jobs without increasing carbon dioxide emissions, at least in the short to medium term. Figure 4.1 shows this relationship for all countries and highlights those in which employment generation has come with a *more than proportional* expansion in carbon dioxide emissions (above the 45-degree dotted line). This group of countries includes Mongolia, Myanmar, Kyrgyzstan, Singapore and Viet Nam, where carbon dioxide emissions have grown between 15 per cent and 40 per cent despite relatively modest expansionary employment dynamics. Countries below the 45-degree dotted line are those where some decoupling has started, but only those below the x-axis have managed to increase jobs without additional impact on the environment.

The poorest-performing countries in this analysis are ones where the carbon dioxide growth rate in 2018 was rising faster than the employment rate. Here we find large middle-income countries such as Malaysia, but also Bangladesh and the Russian Federation, as well as smaller economies such as Romania, the Republic of Moldova, and Paraguay. However, in the vast majority of countries, employment growth outpaced carbon dioxide emission growth, suggesting some initial though tentative signs of decoupling. This group includes countries like the United States where decoupling is only happening marginally. It must be noted that most of the countries are concentrated below the 5 per cent employment growth rate. These are countries where employment expansion has largely slowed down and, in some cases, stalled.

Countries below the x-axis include those that are experiencing a real decoupling. They include European countries such as Germany, France, the United Kingdom of Great Britain and Northern Ireland, Italy, the Netherlands and Spain, as well as Japan. Their reduction in carbon dioxide emissions is, however, relatively modest, below 2 per cent, except in the cases of Germany and France. This highlights the fact that even large advanced economies are struggling to make a decisive shift towards sustainable and inclusive structural transformation. Among the largest developing and emerging economies, the



Source: Based on consolidated data from ILOSTAT (https://ilostat.ilo.org/) and Our World in Data (https://ourworldindata.org/) (100 countries).

Figure 4.1 Employment growth and environmental pressure: growth rates in carbon dioxide emissions and employment, 2014–2018

carbon dioxide emissions growth rate has remained above 5 per cent, India experiencing a 6.82 per cent rate, Nigeria, 12.17 per cent and China, a more modest 3.72 per cent.

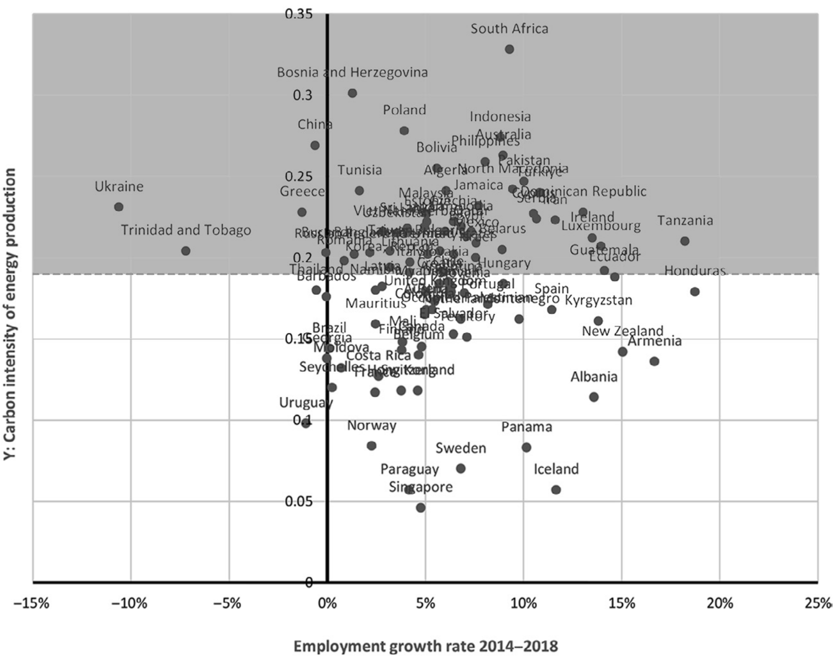
Overall, the analysis shows that even those countries that manage to fall below the 45-degree dotted line find it difficult to accelerate their decoupling and in many cases are stuck on a low employment growth path. Hence there is need to create more jobs while shifting gradually below the x-axis.

An important step in the direction of decoupling employment growth from carbon dioxide growth is to promote a transformation of the energy sector. Such a transformation could reduce the carbon intensity of energy generation and provide a way to dramatically scale up renewable energy technologies.

Employment generation could be compatible with such transformation. In fact, the renewable energy sector is already becoming a major source of employment growth.

Figure 4.2 maps the carbon intensity of energy generation in 2018 against the employment growth rate for the period 2014–2018. Countries above the dotted line are those in which the carbon intensity of energy generation is above the world average at 0.19. Below this line we find those economies in which energy transition has been faster; they include the United Kingdom, Belgium, Spain and New Zealand, among others, as well as France, whose energy system has a strong nuclear component. The only large middle-income economy below the average indicated by the dotted line is Brazil. However, Brazil's employment dynamics were very poor in 2014–2018, and hence the country has not benefited from a coupled energy-efficiency–employment-generation loop.

In the grey zone we find a very heterogeneous group of countries. This heterogeneity can be better understood by matching the information con-



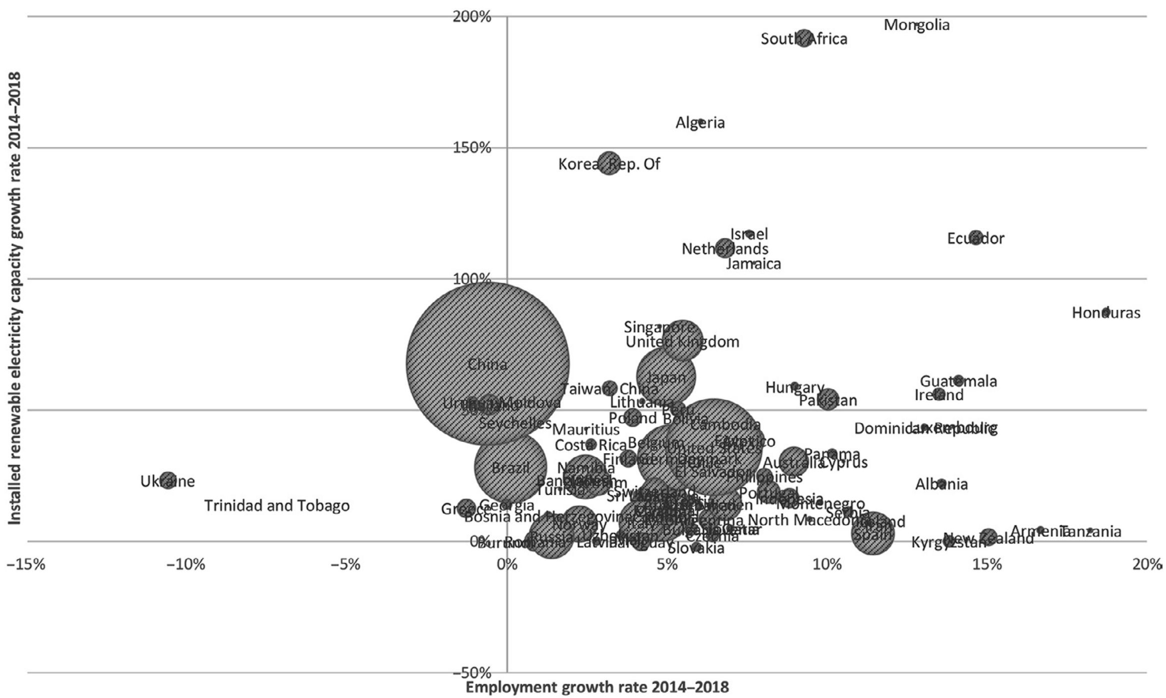
Source: Based on consolidated data from ILOSTAT and Our World in Data.

Figure 4.2 *Energy efficiency of employment growth: carbon intensity of energy production per employment growth rate, 2014–2018* tained in Figure 4.2 with that in Figure 4.3, which maps countries' renewable energy generation, on the vertical axis, and their renewable energy capacity, captured by the size of the bubbles. In the grey zone of Figure 4.2, just above the world average, are large, highly industrialized economies – such as Germany, Japan, Italy and the Republic of Korea – whose productive structure includes several highly energy-intensive sectors. These countries have expanded their renewable energy generation at significant speed and at considerable scale. The United States and Australia are countries in the grey zone in which the expansion of the renewable sector has moved relatively slowly or the sector has not reached a significant size compared with the size of the economy. This is in contrast to Canada, which has obtained a considerable renewable energy generation capacity and is positioned well below the grey zone.

In the grey zone of Figure 4.2 we also find a set of large emerging economies. These include China; South Africa, Indonesia and the Philippines in the Global South; and Poland and Türkiye in Europe and western Asia. Among the countries shown in Figure 4.2, South Africa has by far the highest carbon intensity of energy production. Although it has seen a dramatic acceleration in renewable energy generation, the size of the bubble remains very small. Indeed, South Africa has only recently attempted to accelerate its energy transition. Indonesia and the Philippines have also witnessed some increasing renewable capacity but at a very slow speed. Poland is showing a faster acceleration, pulled by the European Union's highly regulated economy.

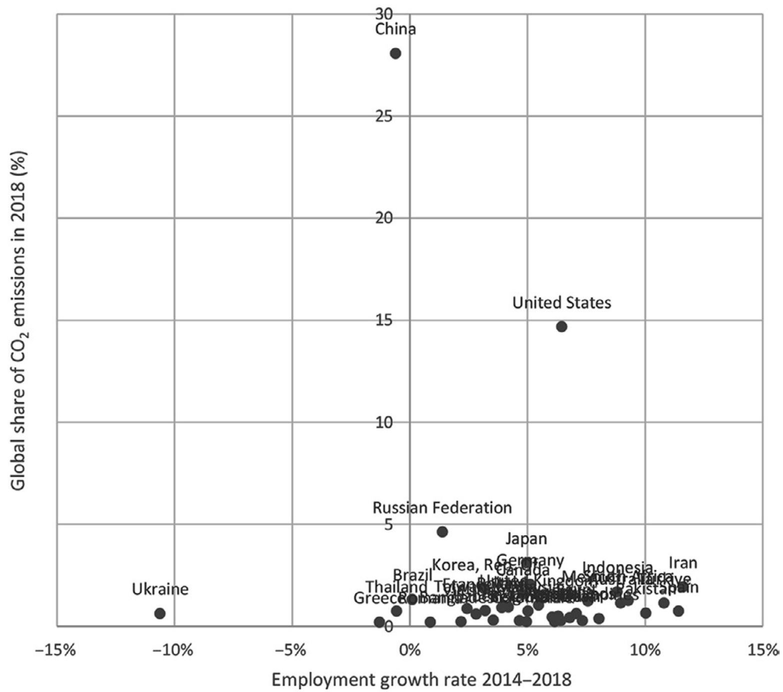
China is certainly the most striking case. The country has still a significant carbon intensity footprint in energy generation, but it has also managed to build the biggest renewable energy capacity in the world (see Figure 4.3). This sector is still growing and becoming a major source of employment generation, despite the contractionary employment dynamic experienced by China in the period 2014–2018. The only other comparable economy with a large renewable sector is Brazil.

The heterogeneous performances of countries, finally, can be illustrated by looking at their global shares in carbon dioxide emissions. Figures 4.4 and 4.5 show the high degree of concentration of emissions in China, the United States and the Russian Federation, followed by Japan and Germany (which two countries account for a much smaller share, below 2 per cent each). These countries are among those with the highest stakes and responsibility. They are also countries with tremendous technological capabilities to drive the transition. The extent to which these technological capabilities have been put into action depends on several country-specific factors, including sector-specific challenges in both the energy and industrial sectors. Countries in the 1–2 per cent band include the largest emerging economies (Brazil, Mexico, Indonesia,



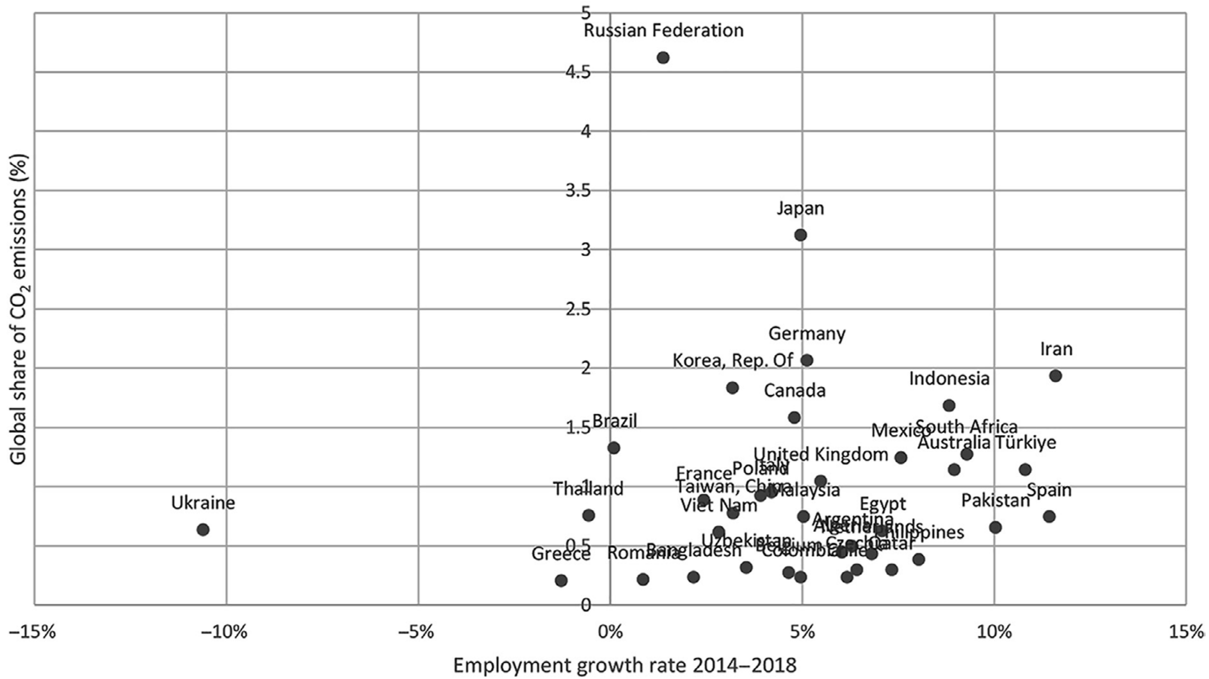
Note: The size of the bubble indicates the renewable energy capacity in MW.
Source: Based on consolidated data from ILOSTAT and IRENA (top 50 countries by MW renewable capacity).

Figure 4.3 Decoupling employment growth and environmental pressure via renewable energy generation, 2014–2018



Source: Based on consolidated data from ILOSTAT and Our World in Data.

Figure 4.4 *Employment growth and global emissions shares: carbon dioxide emissions global share relative to employment growth, 2014–2018*



Source: Based on consolidated data from ILOSTAT and Our World in Data.

Figure 4.5 *Employment growth and global emissions shares: Carbon dioxide emissions global share relative to employment growth, 2014–2018 (excluding China and the United States)*

South Africa and the Islamic Republic of Iran) as well as advanced economies, especially in Europe.

3. FIVE PATHWAYS FOR ENERGY TRANSITION AND GREEN INDUSTRIALIZATION: A SECTORAL PERSPECTIVE

The mapping in section 2 has pointed to a high level of heterogeneity and a severity of challenges that countries face in reducing carbon dioxide emissions while expanding employment. The coupling of decarbonization and employment generation follows different dynamics in different sectors of an economy. Countries have increasingly embraced more sector-specific approaches to developing feasible pathways towards sustainable structural transformation. The most prominent policy initiative is the IEA Breakthrough Agenda 2022, which is supported by several countries and multilateral organizations (IEA 2022b). Each of the supporting countries is setting sector-specific goals and identifying ways in which such goals can be achieved within a sustainable structural transformation framework.

Although in 2019 the energy sector accounted for around 13 gigatonnes of carbon dioxide equivalent ($GtCO_2e$), or 23 per cent of total global emissions, and is therefore central to sustainable structural transformation, decarbonization cannot be limited to the energy sector. All industrial sectors – from agro-food and garments, to chemicals and steel, and aerospace and automotive industries – contribute to climate change differently in direct but also indirect and mediated ways along upstream and downstream value chain segments. For example, the steel sector, a key upstream industry, accounts for around 3 $GtCO_2e$, or 5 per cent of total emissions. That has risen by around 15 per cent since 2010. Agriculture and related land use account for around 10 $GtCO_2e$, or 17 per cent of total emissions. Of those, about 7 $GtCO_2e$ come from direct farmgate emissions. Farmgate emissions have increased by 0.6 per cent per year since 2000.

On the basis of these sectoral differences, we can distinguish five main potential pathways for sustainable structural transformation. These pathways are particularly challenging in developing countries, where constraints and compression mechanisms are more severe given the multiple challenges that developing countries face.

3.1 Pathway 1: Planned Phase-Out of and Final Exit from Fossil Fuel Industry Extraction for Energy Generation and Export

The IEA Breakthrough Agenda 2022 sets very ambitious targets for the power sector globally (IEA 2022b). First, emissions from the power sector should fall by around 8 per cent each year till 2030, while electricity access should reach 100 per cent by 2030, if not before. Investment will need to grow 25 per cent each year, reaching US$2 trillion per annum by 2030. The IEA Breakthrough Agenda 2022 also highlights the need to mobilize the additional 7.4–8 terawatts (TW) of renewable power capacity, and other clean power options, that will be needed globally by 2030.

To achieve these ambitious goals, developing countries need dedicated international support. In particular, in those countries whose export basket and government revenues are dominated by fossil fuel rents (for example, Nigeria) and/or for which coal is still the major source of energy (for example, South Africa), it is not politically feasible to plan a rapid phase-out of the fossil fuel industry without developing alternative sources of revenue and job creation. Opportunities to develop these do exist and must be pursued. In South Africa, for example, proposals have been made to build solar power farms in existing coal-mining sites in Mpumalanga – the state where most of the coal and energy plants are located – and to retrain the workforce and retrofit the grid to channel clean energy into the economy (Andreoni et al. 2022).

In some cases, such phase-out also entails exploring opportunities for infrastructure development, including interconnectors to support the integration of larger shares of low-cost clean power into the grid. The demonstration and testing of power system flexibility solutions, including long-term storage, will be needed to enable planned phase-out alongside new infrastructure development to achieve fully net zero power.

3.2 Pathway 2: Development of New Renewable Technology Industries

The dramatic decline in the cost of electricity from digitally enabled renewables – solar photovoltaics and wind, onshore in particular – has offered a viable pathway for accelerating the energy transition. Furthermore, green hydrogen is becoming a feasible option to replace fossil fuels (especially in highly energy-intensive difficult-to-abate industries such as steel, metal foundries, and chemicals and plastics) as well as liquid fuels for heavy transport and industrial logistics.

Many developing countries do not have technological and organizational capabilities for developing renewable technologies; however, they can leverage their critical minerals and natural capital (sun, wind and hydro) to attract investment in upstream industries (from mineral processing to battery and fuel cell manufacturing) and promote joint ventures, technology licensing and indigenous innovation. Developing countries in the Global South can become energy superpowers and leverage that status to attract investment co-location. Lithium, nickel, cobalt, manganese and graphite are crucial to battery performance, longevity and energy density. Rare earth elements are essential for the permanent magnets that are vital for wind turbines and electric vehicle motors. Electricity networks need a huge amount of copper and aluminium; copper is a cornerstone of all electricity-related technologies. These critical minerals are geographically concentrated. Several African countries are endowed with large amounts of critical mineral resources, which provide important opportunities for these countries in the world's technological development. For example, 70 per cent of global cobalt production comes from the Democratic Republic of the Congo, and over 80 per cent of platinum and manganese resources are in South Africa and Zimbabwe (Andreoni and Avenyo 2023). The Democratic Republic of the Congo and Zambia are also important sources of copper. Leveraging mineral resources for sustainable structural transformation offers a unique opportunity for Africa and other countries such as Chile and Peru, and also for Myanmar and Indonesia, which have large amounts of lithium, rare earths, copper and nickel.

Hydrogen production and use account for around 0.9 $GtCO_2e$ of emissions per year, or 1.5 per cent of total emissions. Renewable and low-carbon hydrogen production currently accounts for less than 1 per cent of global hydrogen production. To increase the availability and affordability of renewable and low-carbon hydrogen, the IEA Breakthrough Agenda 2022 has pointed out the importance of creating larger markets for its deployment and trade, including through purchase commitments (IEA 2022b). This will also incentivize investment in production, which must scale up from less than 1 megatonne (Mt) in 2020 to around 140–155 Mt per year by 2030. Such an ambitious target can only be achieved if governments and companies coordinate full deployment of green hydrogen in those sectors in which green hydrogen is already a proven substitute for fossil fuels (Andreoni and Roberts 2022). Accelerating the deployment of hydrogen in new applications such as steel, shipping, and energy storage requires increasing the number and geographical distribution of demonstration projects, backed by targeted technical and financial assistance, including agreeing on safety, operational and emissions standards in deployment and trade.

3.3 Pathway 3: Decarbonization of Difficult-to-Abate Sectors and Carbon-Intensive Sectors

The so-called "difficult-to-abate industries" (such as iron and steel, chemicals and plastics, and cement) account for more than 50 per cent of all industrial emissions. Countries can move away from the worst fossil fuels towards gas and renewables and, incrementally, free themselves from gas in the direction of blue and green hydrogen (the former relying on carbon capture technologies). For many other relatively less-energy-intensive sectors, opportunities for industry efficiency-enhancing retrofitting will have to be pursued to retain access to global markets. Two sectors (steel and agriculture) are examined below.

(a) *Steel sector.* According to the IEA, the steel sector accounts for around 3 $GtCO_2e$ of emissions per year, or 5 per cent of total emissions. That share has risen by around 15 per cent since 2010. The IEA Breakthrough Agenda 2022 sets an ambitious target for the sector: global average direct emissions intensity of steel production needs to fall by around 30 per cent by 2030 (IEA 2022b). In 2022, less than 1 Mt of primary near-zero-emission steel per year was being produced, whereas over 100 Mt per year will be needed by 2030. Conventional high-emission plants with a production capacity of 114 Mt are currently underway or in planning.

Given the scale and capital intensity of the steel sector, joint procurement commitments by groups of countries and companies could create sufficiently large demand to attract investments. Capital intensity could be further supported by advance purchase commitments to address inter-temporal commitment of finance and specialized capital. The Green Steel Deal is an example of trade measures to ensure that near-zero-emission steel can compete in international markets. Such trade policy measures depend on countries' coordination on definitions and standards for low-emission and near-zero-emission steel, without which procurement and trade will not take off.

(b) *Agricultural sector.* According to the IEA (2022b), agriculture and related land use account for around 10 $GtCO_2e$ per year, or 17 per cent of total emissions. Of these, about 7 $GtCO_2e$ come from direct farmgate emissions, which have increased by 0.6 per cent per year since 2000. Farmgate emissions need to fall by around 20 per cent by 2030. Twenty-seven per cent of all agricultural and land use emissions can be attributed to agricultural products that are internationally traded. Smallholders produce about 30 per cent of global food production.

Along with reducing waste, changing diets and promoting smart agriculture in developed countries, the model for agriculture in rapidly urbanizing developing countries is a critical lever in changing the direction of the world's development. African countries, for example, are net food importers and yet Africa has the areas in the world with greatest potential for expanded sustainable agricultural production, given water availability and without deforestation – for example, in countries like Zambia and Tanzania. As attention shifts to the emissions entailed in consumption (meaning that industrialized countries will consider the carbon costs of the produce they import, and hence mechanisms such as carbon border taxes – see Chapter 7), investment in agriculture in developing countries needs to be consistent with a produce mix (less meat) and production methods that involve much lower emissions. Food supply chains need to be smart, using less fertilizer and pesticides and transporting and packaging the produce more efficiently. Climate-sensitive consumers can verify responsible farming methods if appropriate codes are in place. For example, exports of fresh fruit have boomed from many countries and can earn good returns for producers with traceability in place. Finally, in order to reduce emissions and increase productivity, jobs and resilience, especially among smallholders in developing countries, public finance will be needed to disseminate new sustainable production technologies in the sector.

3.4 Pathway 4: Development of New and Retrofitting of Existing Energy Infrastructure and the Built Environment

Sustainable structural transformation demands new patterns of production as well as consumption, as spelled out in United Nations Sustainable Development Goal 12. These new patterns of sustainable production involve building new and digitally enabled energy systems, governing the critical mineral supply chains underpinning these technologies, and reorganizing the geography of production. These transformations can only work if a new infrastructure of the built environment and everyday life is put in place. Buildings and transport feature prominently in the built environment as two of the most important areas in which patterns of consumption need to become sustainable. These two sectors are key contributors to carbon emissions. Their transformation could generate tremendous demand pulls for sustainable structural transformation, including new green jobs.

Effective deployment of renewable energy can follow several infrastructural models; and old infrastructure can be redeployed to support a more sustainable energy system. Energy infrastructure maintenance and redesign offer opportunities for jobs creation and are moving towards diffused energy governance. Alongside energy infrastructure, road infrastructure is a major contributor to emissions. According to the IEA (2022b), the road transport sector accounts for around 6 $GtCO_2e$ per year, or 10 per cent of total emissions. This figure had risen by 13 per cent since 2010; it needs to fall by nearly a third by 2030. Zero-emission vehicles accounted for around 9 per cent of global car sales in 2021; this should reach about 60 per cent by 2030.

Countries and manufacturers should align target dates for all new road vehicles to be zero emission, in order to shift investment more quickly towards the new technologies and accelerate their cost reduction. This coordination should include mobilizing investment in charging infrastructure, and developing the underlying soft infrastructure – harmonized standards to ensure sustainability in battery supply chains. The manufacturing of electric vehicles is a major contributor of green jobs, and employment generation opportunities can be generated along the battery value chain, including in upstream industries as well as downstream in the maintenance of the charging infrastructure.

3.5 Pathway 5: Circular Economy Models

Circular economy models' main tenet is that it is possible to reduce the pressure on scarce resources by reducing material waste and scrap and incentivizing recycling (see also Chapter 5). These models reinsert material waste and scrap into production processes. For example, agriculture-based economies can utilize organic waste and by-products to produce biofertilizers or bio-stimulants, thereby closing biological loops and simultaneously generating new jobs and income streams. The circular economy pathway is cross-sectoral and links pathways 1, 2, 3 and 4 described above. The deployment of this model is also cross-national and hence points to the need to consider global systemic interdependencies, to improve social inclusion and to generate employment, especially in developing countries. For example, various trade flows can be directly linked to different circularity strategies, including trade in secondary raw materials, in waste and scrap for recovery strategies, in goods for refurbishment and remanufacturing, in second-hand goods and in services. Digital technologies can also enable product dematerialization via advanced new materials and process efficiency – for example, with the deployment of digitally enabled predictive maintenance technologies.

4. WINDOWS OF OPPORTUNITY FOR GREEN JOBS

When considering policies to advance a shift to a sustainable energy mix, it is important to factor in the effects on labour and income distribution. Garcia-Garcia, Carpintero and Buendia (2020) provide a theoretical schematic to unpack various causative mechanisms and channels through which energy transition will ultimately affect labour and incomes. Positive effects are mainly driven by new investments in green technologies, and sectors can open windows to both direct and indirect job creation. The indirect effect originates from a "sectoral multiplier" effect, that is, the generation of jobs in upstream and downstream industries associated with the new green technology investments. For example, the shift towards renewable energy generation technologies is creating jobs in the entire renewable value chain industry, including the post-sale maintenance and repair services required to keep solar and wind technologies in operation. There are also "macro-multiplier" effects that can derive from more systemic changes in the energy mix and the increasing sectoral reconfiguration driven by technologies such as green hydrogen.

Although positive effects are expected to become dominant in the medium to long term once sectors have managed to go through such industrial restructuring, there are also potential negative effects that will be difficult to mitigate in the short to medium term. Negative effects include job losses, owing to decreases of investment in non-green sectors, as well as through the overall increases in prices which may compress disposable income and aggregate demand; hence an indirect negative impact on the job expansion potential of the economy. In this process of transition demanded by climate change, jobs will be substituted, redefined and in some cases eliminated.

A first important attempt to estimate empirically some of the direct effects on jobs comes from recent work by IRENA and the ILO (2022). In their analysis of the evolution of global renewable energy employment, between 2012 and 2021, over 12 million new jobs were created, a third of them from the solar photovoltaic industry. The top three contributors are (i) solar photovoltaic, (ii) bioenergy and (iii) hydropower. Wind energy has provided a more modest contribution to job creation, partially because wind technologies have undergone more limited diffusion and are more capital intensive. Solar heating/cooling, geothermal energy, concentrated solar power, heat pumps and green waste management are among the other sectors that, to date, have brought limited job creation.

The potential for job creation depends on the technology, its diffusion and its value chain structure. For example, the IEA (2022c) has estimated that the solar photovoltaic industry could create 1,300 manufacturing jobs for each gigawatt of production capacity. To be on track to meet the increased demand projected in the IEA's "Net Zero by 2050" scenario, the solar photovoltaic manufacturing sector needs to nearly double the number of jobs globally by 2030. These jobs will be distributed along the photovoltaic value chains and related sectors, such as those involving the manufacturing of components such as glass, EVA (ethylene vinyl acetate), backsheets, inverters and mounting systems. These indirect jobs are anticipated to add a quarter of a million jobs to this industry's total job creation. In contrast, thin-film module manufacturing, which is less job intensive than crystalline silicon technology, creates only around 200 jobs per gigawatt because it entails fewer production steps and they are mostly automatized.

The job creation potential depends on the extent to which countries investing in photovoltaic manufacturing are able to link up into global value chains and markets and link back to their local production systems. The degree of engagement in technology development also impacts on the skills intensity of jobs. Photovoltaic manufacturing requires a diversity of workers, including production engineers, material handlers and assemblers. Owing to the current geographical concentration of the solar photovoltaic supply chain, the majority of skilled personnel are based in China and South East Asia. In many countries, these new skills need to be created and training needs to be scaled up so that windows of job opportunities materialize in the local production system. Demand pull for photovoltaic technologies is also central to encouraging investment and skills development, and public procurement has become an important policy tool for the green transition (see section 5).

As mentioned above, the potential for indirect jobs and the potential sectoral multiplier must also be taken into account. A study by Garrett-Peltier (2017) developed an input–output method to estimate the potential inter-sectoral multiplier effect that renewable energy, energy efficiency and fossil fuels can have on employment. The study uses input–output (I–O) tables to create "synthetic" industries – namely, clean energy industries that do not currently exist in I–O tables – to estimate the employment impacts in the short to medium term of different green and brown investments. The study finds that, on average, 2.65 full-time-equivalent (FTE) jobs are created from US$1 million of spending on fossil fuels, whereas that same amount of spending would create 7.49 or 7.72 FTE jobs in renewables or energy efficiency. Thus each US$1 million shifted from brown to green energy will create a net increase of five jobs.

Recent work by the IEA (2022a) seems to confirm the higher job creation potential of green sectors and the overall global shift in employment generation in the energy sector from brown to green jobs. By using over 15,000 data points on employment and wages gathered from national labour accounts, company reports, in-country experts, international databases and academic literature, the IEA (2022a) has produced a baseline by sector, region, and value chain segment to assess global energy employment. According to their estimation, the energy sector employed over 65 million people in 2019, equivalent to around 2 per cent of global employment. These jobs are roughly equally distributed across fuel supply (21 million), the power sector (20 million) and end uses (24 million) such as energy efficiency and vehicle manufacturing. Clean energy employs over 50 per cent of all energy workers, owing to the substantial growth of new projects coming into operation since the COVID-19 crisis.

Globally, wind and solar already employ the same number of people as the fossil fuel industry. In a number of regions clean energy jobs have already outpaced traditional jobs in the fossil-fuel-based energy sector. Forty-five per cent of the employment in the energy sector is considered to be high skilled, with the sector requiring higher-skilled workers than other industries (see Chapter 9). Many of the skills from brown industries can be also used as a foundation upon which to retrain workers in green energy generation. Such a sectoral shift is also emerging in other sectoral value chains. For example, in the automotive industry, 10 per cent of total employment is already generated in the manufacturing of electric vehicles and their components and batteries (IEA 2022a).

These windows of opportunity for green jobs are opening disproportionally in the Asia–Pacific region, where China alone accounts for almost 30 per cent of global energy employment. In this region, green jobs have emerged as a result of rapid energy infrastructure expansion and relatively lower-cost skilled labour, which together have enabled a demand pull and supply push for the emergence of clean energy manufacturing hubs. These hubs have become the world suppliers for green projects worldwide, notably for solar power and electric and hybrid vehicles and batteries. The emergence of these local production systems and their global strength offer opportunities for countries still catching up in the green transition. The rapid learning curves in solar and wind have been driven by green project investments. However, developing countries may also face obstacles to entering these supply chains as producers. Leveraging the critical minerals essential for the manufacture of digitally enabled green technologies is one of the possible pathways that catching-up countries can follow to break into these new clean energy industries and markets.

The IEA (2022a) have produced some employment estimates, based on a 2019 baseline, to look at employment distribution in the energy sector in 2030. Such estimates are evaluated in two scenarios: the announced pledges scenario (APS), where all announced climate pledges are met on time and in full, and the net zero emissions (NZE) by 2050 scenario, which is consistent with limiting global surface temperature warming to 1.5°C by 2100. According to the IEA, in both the APS and NZE scenarios, job growth more than offsets a decline in the traditional fossil fuel supply sectors, although the new jobs will be created in different sectors from the sectors where jobs used to be. This sectoral employment shift requires retraining and new skills development, and other infrastructural policies to govern and direct a just transition.

5. GREEN INDUSTRIAL POLICY FOR GREEN TRANSITION AND GREEN JOBS CREATION: CASE STUDIES

Historically, the state has played a key role in addressing structural transformation challenges through a range of industrial policies (Andreoni 2016; Chang and Andreoni 2020). It will be no surprise, then, if most countries, both advanced and developing economies, are looking to green industrial policy to decarbonize their economies along the various pathways and to capture some of the windows of opportunity to create green jobs.

Governments can reshape industries, align incentives among institutions and organizations, build coalitions of interests and drive technological and organizational innovation. This does not necessarily mean preselecting certain technological pathways to the exclusion of others, or limiting private sector initiative. On the contrary, the state can steer the search for both sector-specific and cross-sectoral solutions that rely on environmentally sustainable technology. Governments can also de-risk experimentation and innovation efforts, especially in sectors like green hydrogen and energy generation, which require long-term financial commitment. Finally, governments can crowd in private investments and promote the diffusion of renewable technologies by committing to infrastructural investments or by creating demand via public procurement.

Although there are many green industrial policy instruments that governments can deploy, ultimately their effectiveness is likely to increase if policy instruments are effectively aligned (Andreoni and Chang 2019). Coupling of decarbonization and job creation can be only achieved with well-coordinated industrial policy instruments and packages including public finance and public procurement, setting standards and providing technology services along the entire innovation and production chain, from basic research to full deployment and diffusion of new technologies. In the design of each of these industrial policy instruments, various types of conditionalities can be introduced to reflect risk–reward arrangements supporting sustainable prosperity. These conditionalities can operate *ex ante* by setting different types of requirements on the types of firms that can access incentives or by selecting the types of activities to be supported. They can also operate *ex post* by setting specific requirements on firms' future performance or corporate governance decisions (for example, limiting stock buy-backs or dividend distribution). It is no longer taboo to attach conditions to policies such as those on financing and procurement, or on company bail-outs, investment attraction schemes, business restructuring, etc. Experiences from Austria and France during the COVID-19 pandemic are testament to such public–private conditionalities. Conditionalities are a way to steer financial resources strategically and make sure they are retained and reinvested within productive business organizations to improve social, economic and environmental outcomes.

Although green industrial policy has become very popular, very few governments have managed to deploy coordinated packages of interventions including well-designed conditionalities. One of the green industrial instruments that have been more widely used is green taxes (see Box 4.1 for the case of Chile and also Chapter 7). Green taxes are mainly market-fixing "horizontal" measures that rely on market pricing to motivate or discourage specific types of investments. Carbon pricing in the form of carbon taxes is a good example of market-fixing policy. Green taxes have an important role to play (Rodrik 2014), since there is an increasing recognition that markets have failed to internalize environmental costs at the scale and speed required. Markets alone have also proven incapable of promoting the development and widespread diffusion of green technologies or steering economies towards the much-needed energy and industrial transition. The reason is that the market performs poorly in allocating and committing resources under uncertainty, especially when productive and technology assets are highly specialized and when specific markets do not exist yet (Chang and Andreoni 2020).

BOX 4.1 CHILE'S GREEN TAX

Since ratifying the United Nations Framework Convention on Climate Change (UNFCCC) in 1994 and signing the Kyoto Protocol in 2002 and Paris Agreement in 2016, Chile has actively engaged in the formulation of policies and instruments to address the climate change challenge, including a carbon tax called the "green tax". This tax has its basis in Article 8 of Law 20780 of 2014 and entered full operation in 2017. Green taxes have been used in various countries to take into account the negative externalities of pollution while nudging producers, investors and consumers towards more sustainable production and consumption practices.

The Chilean green tax is an annual tax for all owners of large industrial establishments that generate emissions of particulate matter (PM), nitrogen oxides (NOx), sulphur dioxide (SO_2) and carbon dioxide (CO_2) – above 100 tonnes of PM per year, or over 25,000 tonnes of carbon dioxide per year (Law 20780 of 2014). In 2021, the government embarked on a process of further strengthening this tool over a period of six to eight years. These improvements aim, on one hand, to gradually increase the carbon dioxide tax from US$5 to US$40 per tonne of carbon dioxide; the other goal is to extend the tax's scope to cover different emission sources and selectively apply it across sectors, taking into account the different green transition pathways that are feasible.

Following the examples of Colombia and Mexico, Chile also intends to introduce a provision that allows companies to offset their emissions by financing the development of sustainable projects in the country. This compensation mechanism is intended to provide companies with different pathways to reducing their carbon dioxide emissions. The implementation of a more articulated measure, however, requires the establishment of procedures and obligations for the evaluation, verification and certification of projects that reduce emissions. For example, it is important to make sure that the emissions taxed can only be compensated for by projects that reduce emissions of the same pollutant (CO_2, PM, NOx and SO_2).

Development finance and green finance are further policy instruments widely adopted to decarbonize the economy and grow green sectors, technologies and jobs (see Box 4.2 for the case of Thailand). From a directionality perspective, however, more finance is not always the solution. What matters most is the specific type of finance and how it is directed towards addressing grand challenges. Mazzucato and Semieniuk (2017 and 2018) show empirically how financial actors vary considerably in the composition of their investment portfolio and in their selection of green technologies to invest in. They also differ in their approach to high- and low-risk technologies, private actors favouring low risk much more than public ones. Public financial actors tend to invest in portfolios with higher-risk technologies, thereby creating directionality. They also generally increase their share in total investment dramatically over time and can better afford to commit resources amidst uncertainty across a larger portfolio of projects that provide viable *ex post* solutions (Chang and Andreoni 2020).

Public financing is not simply important in terms of delivering portfolios of viable innovative solutions and crowding in private investors (Mazzucato and Penna 2017). It is also critical to addressing problems associated with the effective scaling up, deployment and diffusion of new technologies. These problems are particularly challenging in economies affected by the "middle-income technology trap" (Andreoni and Tregenna 2020), that is, lack of a well-funded set of intermediate technology institutions and of small and medium-sized enterprises (SMEs) big enough to be capable of absorbing new technologies for energy transition. A combination of weak supply push and demand pull dynamics levels down overall investment and makes gaps along the innovation and production chain even more problematic.

BOX 4.2 THAILAND'S PROMOTION OF GREEN GROWTH AND BIOECONOMY

The Global Climate Risk Index ranks Thailand as eighth out of the ten countries in the world most affected by extreme weather events between 1999 and 2018, the resulting losses estimated to be almost 1 per cent of gross domestic product (GDP) per year over the same period (Eckstein, Hutfils and Winges 2019). The agricultural sector is expected to have borne the brunt of the impact, which has affected the livelihoods of farmers and rural communities. Expected sea level rise is of concern, given the location of Bangkok and key industries along the exposed coastline of the country. Thailand's vision of transitioning its economy into an innovation- and technology-driven "Thailand 4.0", especially through its "bio, circular and green" (BCG) economy model, will not be achievable without significant progress towards green growth. The Thai government's vision of bioeconomy is to modernize agriculture by adding value to raw materials from farmers' fields. This value addition, in the government's view, can help Thailand overcome the middle-income trap, as well as reduce inequality, create jobs and ameliorate the environmental impacts.

Public finance plays an important role in spurring green investment in Thailand. Two on-budget funds – the Energy Conservation Promotion (ENCON) Fund and the Energy Service Companies (ESCO) Fund – have been important precursors to action on energy conservation and efficiency and have also helped Thai banks to develop green lending. The main drivers of investments have been investment incentives, including concessional finance, to promote new green businesses and projects, as well as to encourage "non-green" projects to take up more efficient technologies and improve their environmental performance. Green sectors actively promoted by the Thai Board of Investment (BOI) through this strategy include renewable energy and biodegradable plastics. Other incentives include tax-based incentives, such as exemptions from corporate income tax or import duties, and non-tax-based incentives, such as waiving restrictions on foreign ownership and granting permission to bring in skilled foreign workers. Thailand has also implemented various subsidy schemes to kick-start the renewable energy market. For example, in 2014 the government introduced a feed-in-tariff (FiT) scheme and a competitive bidding mechanism for projects (IRENA 2017). The system was run as a reverse auction where project proponents competed on pricing, with the FiT set as the ceiling price. The FiT covers several sources, including community ground-mounted and rooftop solar, waste-to-energy plant, biomass, biogas and wind.

Source: Based on Organisation for Economic Co-operation and Development (OECD) 2021 and Stockholm Environment Institute (SEI) 2020.

Although supply-side measures like green finance are essential, a green industrial policy must ensure that investments into low-carbon innovation are rewarded and, when markets do not exist, that they are created. Governments tend to focus their attention on supply-side intervention such as tax credit and subsidies, even when the additionality of these measures and the extent to which these types of incentives are sufficient remain unclear. Demand-side measures, especially procurement policies, can play a central role in energy transition, especially given the important role the public sector plays in energy supply and infrastructure management (see Box 4.3 for the case of South

Africa). Public procurement can be used to perform various functions (Edquist and Zabala-Iturriagagoitia 2012).

First, public procurement can create (or increase) the demand for products – goods and services – as well as emerging technologies. This is particularly important in areas where markets tend to underinvest or where infrastructure bottlenecks have to be overcome to make the use of certain technologies viable. Second, if markets do not exist, public procurement can be used to contrive demand and the conditions for competitive processes whereby new firms emerge and old ones are encouraged to diversify into new technology areas and markets (in some cases shifting away from their old core business).

BOX 4.3 SOUTH AFRICA'S PROCUREMENT REFORMS AND CLUSTER MODELS

South Africa's inability to ensure its economy has a reliable electricity supply has without doubt been an important contributor to the country's low economic growth and inability to create jobs and economic opportunities for its citizens – that is to say, to its halting structural transformation (Andreoni et al. 2021). South Africa is also a disproportionate contributor to climate change, and its power generation is largely coal based. Therefore, an accelerated electricity sector transition is the key to South Africa's sustained economic recovery. Several coal power stations that were built decades ago are at the end of their lives and can now be replaced by an energy mix including large-scale investments in renewable energy sources. Such building of new electricity generation capacity is being implemented via government procurement instruments, such as the Integrated Resource Plan (IRP2019) and Risk Mitigation Independent Power Producer Procurement Programme (RMIPPPP).

After competitive bidding processes, Eskom – or a future central entity following the restructuring of Eskom – will procure this additional electricity via purchasing power agreements and will pass on the costs of such electricity to consumers. As for the deregulation of independent power generation, the IRP2019 states that "The development of generation for own use must also be encouraged through the enactment of policies and regulations that eliminate red tape without compromising security of supply." This is the most effective option to reduce the supply gap in the short term. In 2021, reforms were announced to allow a licence exemption for independent power generation projects of up to 100 megawatts (MW). It is also expected that the regulations will allow firms to sell excess power to unrelated parties and to "wheel" excess electricity across the grid for a fee.

In South Africa, coal production and energy generation are geographically concentrated in the Mpumalanga province. The province faces a multitude of socio-economic and environmental challenges, including high levels of unemployment, inequality and poverty as pressure mounts to transition away from a coal-based economy. The Mpumalanga provincial government has been proactive in exploring opportunities to transition the region to a labour-absorbing green-focused economy, hence creating a positive loop between green transition and job creation. Among the many opportunities, the government is focusing on repurposing land on ultimately decommissioned mines and coal-fired stations to pivot to renewable energy production, utilizing the existing transmission assets in the region. Alongside the repurposing opportunities, the government is also interested in specific investment opportunities in the agricultural sector, where a large segment of the population works. Sector-specific opportunities include: renewable energy applications, regenerative agriculture, controlled environment agriculture, smart farming and precision agriculture, and agri-waste management. The Mpumalanga Green Cluster Agency was created to capture such opportunities and coordinate efforts among businesses, government, academia and civil society in the direction of a just transition. By supporting these stakeholders, the agency aims to facilitate more investment and stimulate job creation in Mpumalanga's green economy.

Source: Based on Andreoni et al. (2022) and https://mpumalangagreencluster.co.za/.

Furthermore, public procurement can set the standards and regulatory requirements (on, for example, emissions, performance targets, energy intensity) under which the products and technologies are both produced and deployed. Standard-setting is of central importance not simply because it can be used to shape the emerging markets and industry; it is also central to coordination among innovation and technology investments (Blind and Thumm 2004).

Technology services and access to infra-technologies (such as data, prototyping and metrology systems) also matter greatly in the scaling up of a decentralized and more resilient energy system (see Box 4.4 for the case of the United Republic of Tanzania). Manufacturing extension services can help small and medium-sized firms to adopt sustainable manufacturing processes and technologies along sectoral value chains.

BOX 4.4 THE UNITED REPUBLIC OF TANZANIA'S DIFFUSION OF RENEWABLE ENERGY TECHNOLOGIES

Sub-Saharan African countries are among the most electricity-deprived countries in the world. The lack of sufficient electricity generation results in large segments of the population – especially in remote areas – being deprived of reliable and affordable electricity. In urban areas the increasing population has also brought new pressures on the existing capacity and electricity infrastructure. Despite some notable progress in some countries since the 1990s, governments have been facing mounting pressure and trade-offs, including: the need to increase access while keeping electricity affordable through subsidies; managing stranded electricity generation assets such as coal plant (and related powerful interests) while investing in scaling up renewable energy technologies; and leveraging domestic investments and meeting international private investors' conditions for developing electricity generation capacity.

Electrification has sped up over recent years, and ambitious plans have been confirmed by the Tanzanian government. The United Republic of Tanzania is expected to more than double its energy needs by 2040, and these needs will need to be met with a different mix of energy generation technologies. Increasingly the lowest-cost option is wind or solar. The average levelized cost of energy (LCOE) for utility-scale solar photovoltaic and onshore wind is now often below gas (average LCOEs being US$56 per megawatt-hour (MWh), US$50 per MWh and US$71 per MWh, respectively, according to IEA and Nuclear Energy Agency (NEA) (2020) projections), and records for lower electricity pricing from solar and wind projects fall every year (CDC Group 2021). Furthermore, off-grid or micro-grid renewable energy solutions – most notably, solar energy options – provide a viable alternative source of electricity and opportunity to continue improving both access and connectivity for regions facing the risk of disconnection from the grid via transmission infrastructure degradation. The implementation of such decentralized alternative infrastructure will require localized offices and expertise, employing local labour to maintain the equipment and thereby providing new economic growth and employment opportunities for those dwelling in rural areas. Off-grid or micro-grid solar can accelerate the roll-out of geospatial network expansion plans by establishing forward hubs of supply that delayed transmission infrastructure may later hook into.

Source: Based on Andreoni et al. (2021).

6. CONCLUSIONS

Over the last decade, and in particular since the Paris Agreement, climate change has taken central stage in governments' policy agendas. Furthermore, governments have become increasingly aware of the importance of coupling the decarbonization agenda with job creation. Nevertheless, despite several rounds of international negotiations and commitments at Conferences of the Parties, progress has been slow and in some cases countries have regressed and scaled down their ambitions in the face of new challenges. Much more investment in and widespread deployment of green industrial policy instruments are needed to transform the energy sector and move other carbon-intensive sectors towards more environmentally sustainable pathways.

In this chapter we have found that countries have been struggling to improve their environmental sustainability while creating jobs. Although several factors contribute to job creation dynamics, more sustained investment in green sectors and jobs could have both a direct and multiplier effect across the economy. There is increasing evidence that several windows of opportunity for job creation are associated with renewable technologies as well as with green technologies for sustainable mobility.

Windows of opportunity for green jobs are opening too slowly, however. Well-coordinated packages of green industrial policies are needed to ensure that investments are directed and coordinated, new green markets and infrastructure are created and companies are able to operate more sustainably. There are several country experiences across the Global South of more or less successful implementation of green industrial policy instruments. We have looked at the experience of a few of them in relation to the most well-known and used policy instruments: green taxes (Chile), public finance (Thailand), public procurement (South Africa), and technological services to support renewable energy uptake and training for green jobs (the United Republic of Tanzania).

No policy instrument alone is sufficient, especially when countries want to couple decarbonization and job creation. I have emphasized how packages of well-aligned policy instruments and conditionalities can have a more transformative impact at the sectoral and cross-sectoral level. Taking such an approach to green industrial policy means considering the overall structural transformation of the economy and going beyond only the creation of direct green jobs. Ultimately, in a transformed economy, all jobs should be sustainable. It is essential to create new jobs and retrain workers in order to move towards this scenario.

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